Human Library for Emergency Evacuation in BIM-based Serious Game Environment

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ABSTRACT

It is difficult and most of the time virtually impossible in reality, to conduct an evacuation test to study human behavior in the building condition during the emergency situations (e.g. a burning building). Therefore a serious game engine integrated with rich building information can provide an effective and efficient alternative. A new serious gaming approach, based on Building Information Modeling (BIM), integrated with rich building information can simulate different emergency situations. It can also provide a 3D visualization and an interactive way for exploration of the effect of building conditions on human behavior during the evacuation process. However, human behavior and reaction to the emergency environment is one of the most important but hard to predict perspective in the prediction of emergency evacuation time and results. Consequently, the development of a human library that contains validated human egress behaviors is the key to the simulation of evacuation in an emergency environment and developing an accurate emergency evacuation analysis. This study develops the framework to build the human library through a BIM based gaming environment. Parameters of human beings that should be considered are discussed and the values of these parameters are collected from the players of the developed emergency scenario (game). The repository of human library is based on the framework of Agent Based Modeling (ABM) where human behavioral data is encapsulated as methods of agents. To overcome the limitations related to individual human factors, the hypothesis is that human behavior can be explored in a serious cyber game and the decision made by the human in the game scenario is identical to the decision during the same situation in the real world.

INTRODUCTION AND PROBLEM STATEMENT

The frequency of terrorist attack and collective human disasters appears to be increasing (Elliott and Smith 1993; Helbing et al. 2000a). Efficient emergency simulation approaches can help building managers develop effective rescue and evacuation plan when an emergency or disaster happens (Wang et al. 2011; Zhang et al. 2012). Among emergency simulation approaches, consideration of human behavior factors in evacuation simulation is a big challenge for safety engineers (Rüppel and Schatz 2011). Most present evacuation simulation models are based on Agent Based Modeling (ABM) approaches (Rüppel and Schatz 2011). ABM is capable of capturing complex behaviors at the microscopic level and reproducing the "mass behaviors" in a bottom-up manner (Du and El-Gafy 2012). Despite the great success of existing ABM simulation studies, many of the behavioral models are incompletely represented, inconsistently developed or difficult to access, susceptible to omissions and several other limitations (Gwynne 2011).

On the other hand, conversion of a 3D model to a VR model and keeping the VR model up to date is time and money consuming. Augmented and virtual reality for a realistic visualization of the emergency environment has been investigated to solve these problems (Rüppel and Schatz 2011). The idea of using computer game technology to build virtual world is raised by Trenholme and Smith to optimize resource in complex process of building realistic virtual environments (Trenholme and Smith 2008). They propose the rapid prototyping of emergency fire virtual environment by using computer game technology (Smith and Trenholme 2009). One problem encountered when using augmented and virtual reality for developing an emergency virtual environment, the game players always know it is a virtual world but not a real world, and as a results, their behavior and reaction to the emergency scenario may be different from their action in real emergency events.

LITERATURE REVIEW

This section summarizes previous related research that provide as a basis of our proposed methodology to solve the problem of human behavior consideration in emergency evacuation simulation.

BIM and Virtual Reality Game for Emergency Evacuation. Ruppel and Schatz introduced the concept for a BIM-based Serious Human Rescue game (Rueppel and Stuebbe 2008; Rüppel and Schatz 2011). The work combined BIM and serious gaming technology into the building safety application. They make it possible to extend BIM applications to integrate human factors. Ruppels and Schatz believes their work can bridge technology between the real and virtual world in the game(Tizani and Mawdesley 2011).

Socio-psychology and Physics Models. Helbing studied crowd stampedes and summarized nine characteristic features of escape panic based on socio-psychological literature, media reports, previous video materials, empirical studies and engineering handbooks. They simulated the crowd dynamics of pedestrians by using a

"generalized force model"(Helbing et al. 2000b). Factors affecting the pedestrians' behavior are considered as socio-psychological and physical forces and they built the pedestrian behavior simulation model that form the quantitative theories of predicting crowd dynamics (Helbing et al. 2000a).

Besides Helbing's social force model, individual pedestrian/evacuee's movement is also studied by several other microscopic models such as cellular automation model (Burstedde et al. 2001; Kirchner and Schadschneider 2002; Varas et al. 2007) and random walk model (Tajima et al. 2001). Tajima investigated pedestrian channel flow at a bottleneck and T-shaped channel with the biased random walk model(Tajima and Nagatani 2002). In addition to the microscopic model discussed above, emergency evacuation problems can be analyzed by macroscopic models, which are used to produce lower bounds for evacuation times without consideration of individual behavior during the emergency scenario (Zhang et al. 2012). One macroscopic study is the network flow model presented by Kim et al. by using mathematical graph(Kim et al. 2008)

Agent-Based Emergency Evacuation Simulation. Berg etc. proposed a new concept "Reciprocal Velocity Obstacle" to simulate real time multi-agent navigation. Their study assumed agents navigate without explicit communication with each other and simulation of hundreds of agents in densely occupied environments showed that real-time and scalable performance is achievable with static and moving obstacles (Van den Berg et al. 2008).

Pan developed MASSEgress (Multi-Agent Simulation System for Egress analysis) which incorporates diverse human behavior such as competitive behavior, queuing behavior, herding behavior, leader-following behavior into evacuation simulation(Pan 2006). In Pan's simulation, human being's attributes such as radius of whole body, average walking velocity, maximum running velocity are from Eubanks and Thompson' work (Eubanks et al. 1998; Thompson et al. 2003). In order to find out human factors, researchers used different approaches including interviews, questionnaires, experimentation and the analysis of past emergency situations records from media or public record. The emphasis of these data-collection work was to find out mobility parameters such as motion speed, required space of people at different ages and genders (Rüppel and Schatz 2011).Visual Agents in these studies act according to their pre-programmed behavior and decision making rules. These rules consider individual agent behavior, interactions among agents and group behaviors(Pan et al. 2007).

Rodriguez et al. (2012) investigated how the egress of pedestrians/agents was affected by their evacuation environment with consideration of complex egress scenarios, which included "pedestrians, vehicles, guidance agents and environment effect on agent flow" in order to have an informative and sensible building design decision. (Rodriguez et al. 2012). Ruppel and Schatz provide a comprehensive literature review in ABM evacuation simulation(Rüppel and Schatz 2011).

PROPOSED METHODOLOGY/APPROACH

To solve the problem described in the problem statement section, we propose using an online immersive game engine to solicit real human behaviors. The research steps are shown in Figure 1.

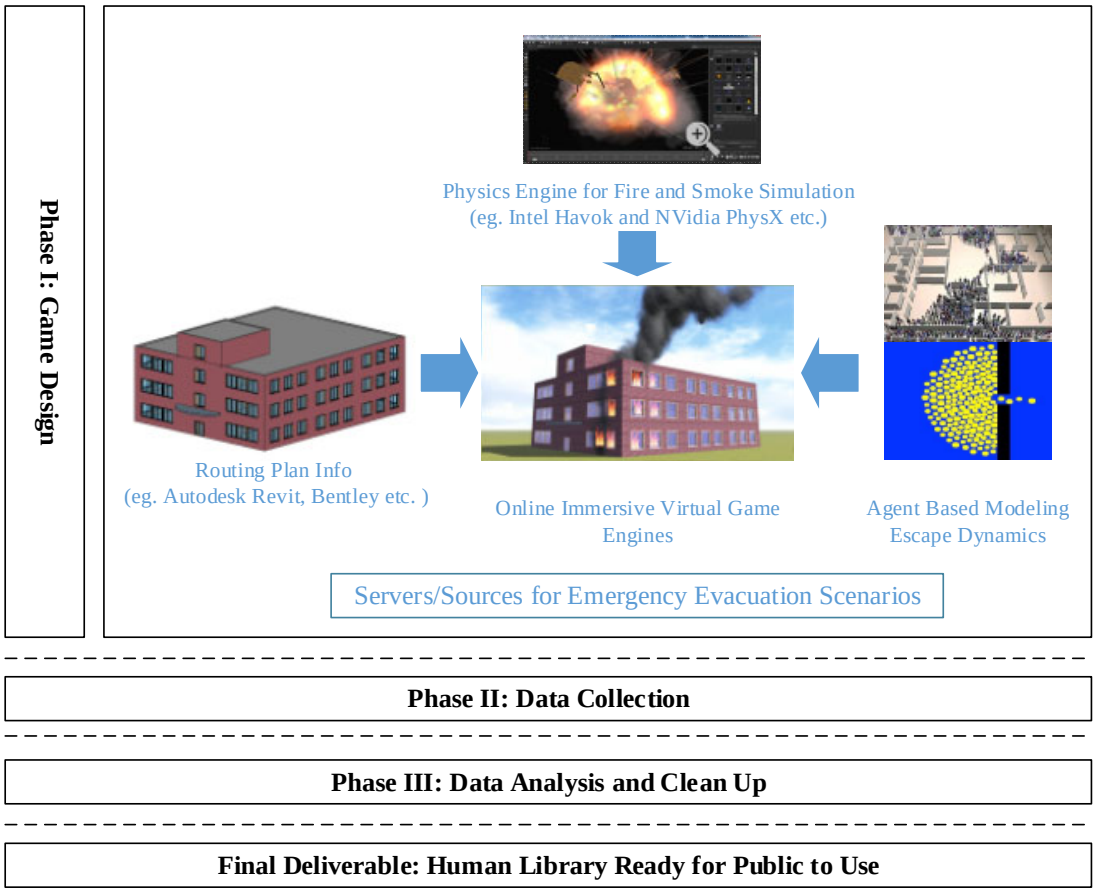

Figure 1. Integrated Approach for the Construction of Human Egress Behavior Library

BIM-based virtual reality (VR) and Agent Based Modeling (ABM) were studied separately, an integrated approach that can solicit and collect real world human egress behaviors is necessary for future emergency evacuation research studies. The framework of the integrated approach is illustrated as in Figure 1. To solve the emergency evacuation simulation with collective human behavior, a multidisciplinary effort is necessary.

Building information models serve as sources of the game scenarios. The BIM model and the game engines provide different building environments with various building types and routing plans, and as a result different emergency scenarios. Online games with immersive virtual reality (IVR) to solicit and collect human egress behaviors will be created and make accessible to the public. IVR provides an enhanced VR

environment, which makes the behaviors in games closer to reality, and more entertaining.

In Phase II, a human egress behavior library (HEBL), which contains human egress behaviors collected from the game will be constructed and a data portal that downloads behavioral modules from HEBL for repeatable agent evacuation simulation will be established. A range of typical scenarios may also be built (such as different types of buildings or different routing maps in the buildings) as base models to compare the results. For some of the human parameters such as average walking velocity, maximum running velocity, etc. , data collection can be supplemented by existing studies such as Eubanks et al. (1998)and Thompson et al. (2003).

Human Library Object Definition. Different classes, that represent various pedestrians, inherit from the same abstract class, which for the purpose of this study is labeled EPedestrian. Currently, the attributes and operations interfaces are defined as shown in Figure 2.

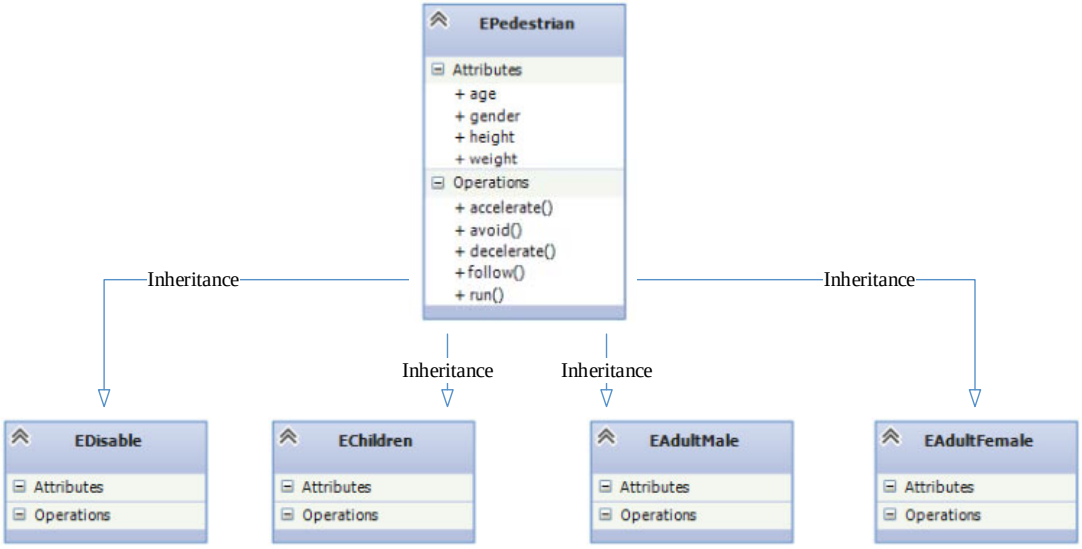

Figure 2. Encapsulated Class Demonstration

Data Collection. End users' behavior and attributes are collected by the web server, no matter what terminal devices they use (e.g. PDA, laptop, desktop tablet, or smartphone) with the immersive glasses, the user is provided a gaming environment similar to real world (Handrahan 2012).

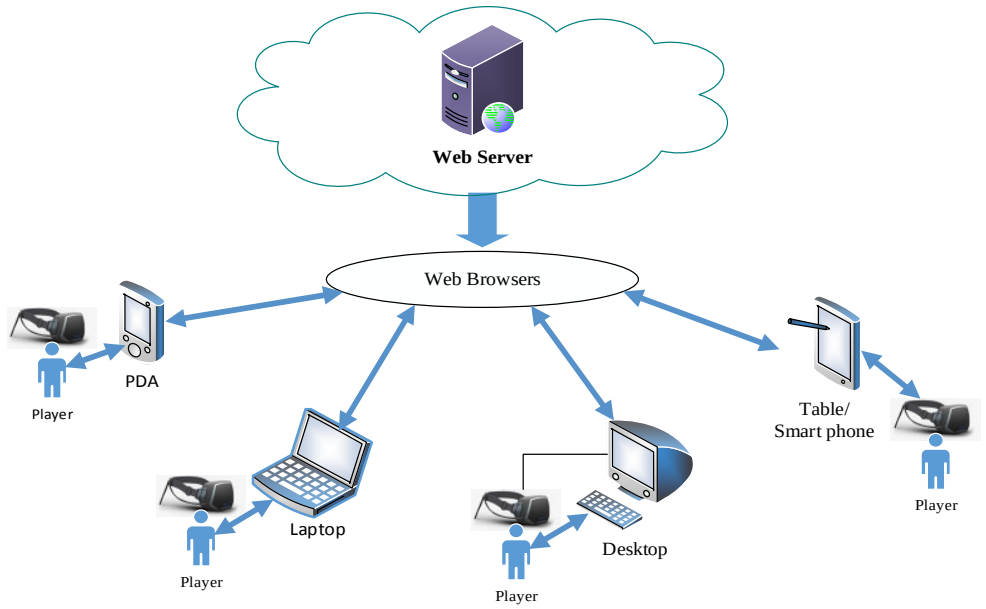

Figure 3. Player Behavior Information Collection

Library Portal Construction. While the end users play the designed game, their behavior information with their attributes information will be collected and saved to the human library database server. After a massive population played the game, the data collected will be analyzed and categorized for use in future human egress behavior studies.

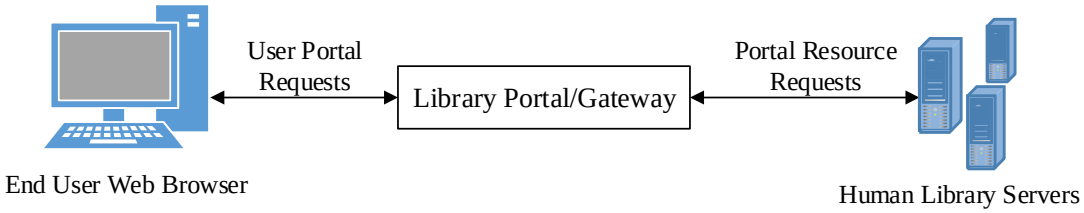

Figure 4. Library Portal Demonstration

Human Library Implementation. Human agent behaviors are collected for future simulation. Once the building model, agents and state are constructed, this information passes to the reasoning module, this model is responsible for molding agent reasoning and generating the optimized strategies to achieve the objectives of different simulation purposes. Objectives can be shortest evacuation time, safe route, lowest fatality rate, individual objectives and the system objectives are different.

This approach will be implemented and tested in different building environments, such as commercial office building, school projects with children pedestrians, shopping mall, and concert hall (in occupied scenario).

The game designed can also be used for training purpose. For example, after playing the game for multiple times, the total evacuation time and the fatality rate may change, a design change of the building environment or the managed evacuation routing plan may also change the evacuation time and fatality rate. Based on such

simulation, better designs for emergency evacuation or better evacuation plans can be developed and implemented. In residential projects, the game environment can provide the residents familiarity with their emergency evacuation route and possible situations they may encounter in that situation, which will help them obtain optimized results

CONCLUSION

This paper discussed the possibility of the integration of BIM, immersive games, online games, and socio-psychology and physics models to solicit and collect real human behaviors in different emergency scenarios. The data collected will be used to complete the human behavior library and make it available for future emergency evacuation simulations.

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